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Role of Biofertilizers in Pulse Production

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Introduction

Pulses are important commodity group of food crops that can play a vital role to address national food and nutritional security and tackle environmental challenges. In India, pulses are generally produced in poor soils not suited to other crops, with a minimum use of resources and have a very low water footprint. They are vital constituent of cropping and consumption pattern. Of the total net sown area of 141.40 M ha, 52 % *i.e.* 73.20 M ha is rainfed. The pulses cultivation occupies major area under this ecology. Pulses play a greater role in sustaining the economy of the rainfed farming community in a variety of ways.

Bio fertilizer and its role

Biofertilizers are defined as preparations containing living or latent cells of efficient strains of nitrogen-fixing, phosphate-solubilizing or cellulolytic microorganisms which on application to seed, root or soil help in mobilization of nutrients from their natural, non-available forms to available forms through biological activity and help build up soil microflora and in turn improve soil health. They increase soil fertility and help plant growth by increasing their numbers and biological activities. They make the nutrients available by facilitating the uptake of nutrients from root rhizosphere zone and majorly fix the gaseous nutrients from atmosphere. Biofertilizers are the source of increasing the productivity and sustainability of the soil. The application of biofertilizers reduces the risk of soil acidification and contamination of the groundwater. Chemical fertilizers directly increase the soil fertility by adding nutrients into the soil, whereas biofertilizers are helpful in nutrient uptake as their main function in soil is to either fix a nutrient on soil surface that is subjected to greater loss or to solubilize a nutrient that is not available to plants because of fixation on the soil surface.

Some of the important biofertilizers include *Rhizobium*,*Azotobacter*, *Azospirillum*, Phosphate-Solubilizing Microorganisms (PSMs), Arbuscular Mycorrhiza (AM), Plant

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Growth Promoting Rhizobacteria (PGPR), Blue Green Algae (BGA) and *Azolla*. Besides these, another interesting biofertilizer includes *Piriformospora indica*, which is a cultivable endophytic fungus, colonizes plants roots and helps in promoting plant growth and biomass production (Varma *et al.*, 1999). Biofertilizers with pulse crops have done symbiotic relationship mainly *Rhizobium* and others has capacity to fix on an average of 40- 250 kg N $ha^{-1}year^{-1}$.

A wide range of biofertilizers consist of one or more microorganisms which when applied to plants may help to provide various nutrients and in turn, promote overall plant growth. They help plants in fixing nitrogen, solubilizing and extensively accessing phosphorus, combating abiotic stresses, bio-control and siderophore production.

Table 1: Different biofertilizers that were used for different pulse crops are as follows

Biofertilizers	**Recommended crop**	**Capacity of nitrogen fixation Kg ha^{-1}**
Mesorhizobium sp., Ensifer meliloti	Chickpea	5-140
Rhizobium leguminosarum	Pea	17-245
Bradyrhizobium sp.	Green gram	10-112
Bradyrhizobium sp., sinorhizobium fredii	Red gram	7-234
Rhizobium leguminosarum bv. Viceae	Black gram	21-140
Rhizobium gallicum	Common bean	0-125
Rhizobium leguminosarum	Lentil	10-190
Phosphate solubilizing bacteria	Almost all the pulse crops	Variable with different soils

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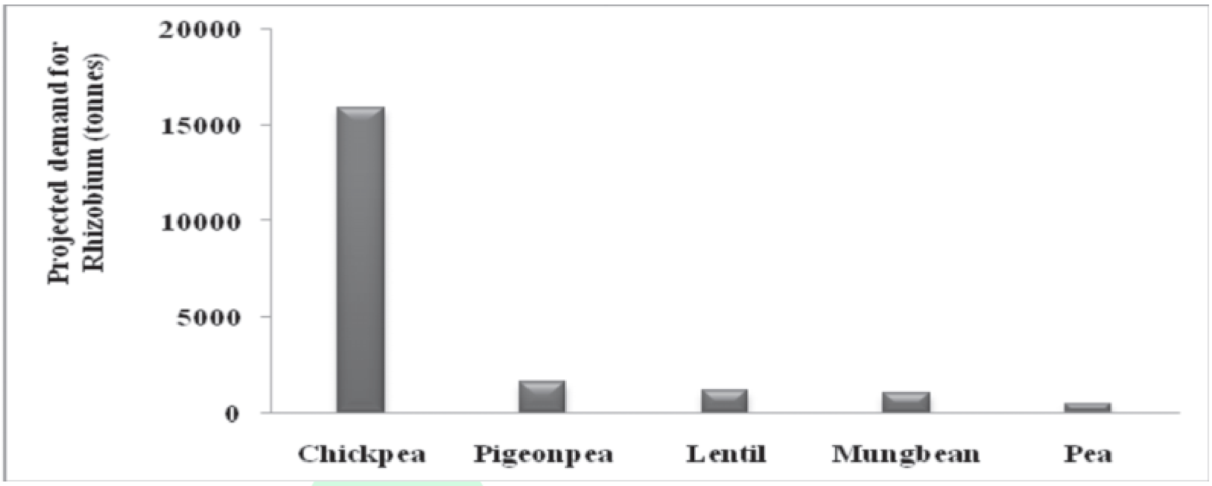

Fig. 1: Projected estimation of *Rhizobium* demand for pulse cultivation (Swarnalakshmi *et al.*, 2016)

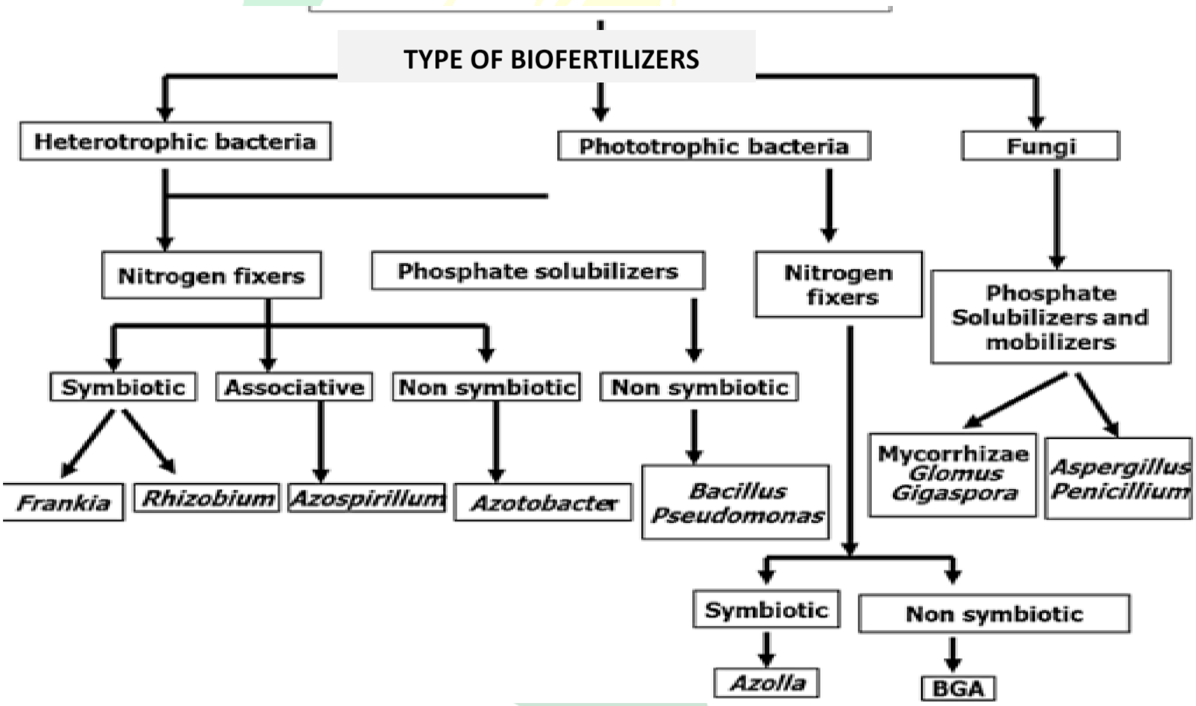

Fig. 2: Types of biofertilizer and their functions(Motsara *et al.*, 1995)

Types of biofertilizers used in pulses

1. ***Rhizobium*:** It is a predominantly used biofertilizer for N uptake and enhanced yield in pulses. It is aerobic bacteria fixes atmospheric nitrogen in legumes symbiotically. The bacteria infect the legume root and form root nodules within which they reduce molecular nitrogen to ammonia. It has been estimated that 40-250 kg N ha^{-1} $year^{-1}$ is

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fixed by different legume crops by the microbial activities of *Rhizobium*. The *Rhizobium* legume association yield increase by 10-30%.

2. **Phosphate Solubilizing Biofertilizers (PSB):** It is a group of heterotrophic moss are known to have the ability to solubilize inorganic phosphorus from insoluble source.

   Bacteria – *Bacillus spp., pseudomonas spp.*

   Fungi- *Aspergillus spp., penicillium spp., Trichoderma spp.*

   Yeast – *Pchwamiomyces occidentails*

   The phosphate solubilizers also produce fungi static and growth promoting substances which influence plant growth. PSB can be used for all crops including paddy, millets, oilseeds, pulses and vegetables.

3. **Vesicular Arbuscular Mycorrhiza (VAM):** It is a fungus, colonize the plant root system and increase the growth and yield of crop. It produces growth-promoting substances. It increases nutrient uptake particularly P, Zn, and other micronutrients. VAM inoculation improves water relation of the plants.

4. **Plant Growth Promoting Rhizobacteria (PGPR):** This group of bacteria colonize roots or rhizosphere soil. These PGPR are referred to as bio stimulants and the phytohormones as they produce indole-acetic acid, cytokinin's, gibberellins and inhibitors of ethylene production. Some common examples are *Pseudomonas, Erwinia, Mycobacterium, Mesorhizobium, Flavobacterium*, etc.

Table 2: Various biofertilizers used in pulse crops

Biofertilizer strains	Function
Rhizobium	N_2 fixation
Bacillus megaterium var. phosphaticum, Bacillus subtilis, Bacillus circulans, Pseudomonas striata, Penicillium sp., Aspergillus awamori	P solubilization
Glomus sp., Gigaspora sp., Acaulospora sp., Scutellospora sp. and Sclerocystis sp., Piriformospora indica	P mobilization
Pseudomonas sp., Bacillus sp.	Plant-growth promotion
Bacillus, Pseudomonas, Trichoderma	Bio-control of soil-borne pathogen

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Beneficial attributes of biofertilizers in pulses

Nitrogen fixation

The success of pulse production depends on Biological Nitrogen Fixation (BNF) attributes of *Rhizobium*, and efficient nitrogen fixation occurs with development of root nodules which are induced by bacterial symbiont with host plant in a specific manner. The plant provides energy to fix N_2 by the symbiont and plant in turn receives fixed nitrogen from the nodule. Since several species of *Rhizobium* are reported to be specific for different pulse crops (Table 3). Therefore, selection of appropriate *Rhizobium* inoculants is essential to achieve an effective symbiosis with the pulse crop introduced to new areas.

The effect of symbiotic performance depends on the host genotype and strain efficiency. Different chickpea genotypes showed variable responses in terms of nitrogen-fixing ability, nodulation potential (nodule number and nodule weight plant^{-1}) as well as plant growth under phytotronic conditions with different *Mesorhizobium* strains (Swarnalakshmi *et al*., 2012). These results clearly indicate the necessity of selecting an appropriate cultivar–strain combination to achieve the full benefit of biological nitrogen fixation.

Table 3: Symbiotic association between *Rhizobium* and pulse crops

Pulse crop	***Rhizobium* species**
Chickpea (*Cicer arietinum)*	*Mesorhizobium* sp., *Ensifer meliloti*
Pigeonpea (*Cajanus cajan*)	*Bradyrhizobium* sp., *Sinorhizobium fredii*
Greengram (*Vigna radiata*)	*Bradyrhizobium* sp.
Blackgram (*Vigna mungo)*	*Rhizobium leguminosarum* bv. *Viceae*
Lentil (*Lens culinaris*)	*Rhizobium pisi, Rhizobium leguminosarum* bv. *viceae*
Pea *(Pisum sativum*)	*Rhizobium leguminosarum* bv. *phaseoli, Rhizobium etli,*
Common bean (*Phaseolus vulgaris*)	*Rhizobium gallicum*

Table 4: Proportion (*Ndfa) and range of nitrogen fixation in important pulse crops

Pulse crops	*Ndfa (%)	Amount of nitrogen fixed (kg N ha^{-1})
Chickpea	8–82	3–141
Pigeonpea	10–81	7–235

Lentil	39–87	10–192
Common bean	0–73	0–125
Greengram	15–63	9–112
Blackgram	37–98	21–140
Pea	23–73	17–244

*Ndfa: nitrogen derived from atmosphere

Phosphorus Nutrition

In addition to *Rhizobium*, phosphate-solubilizing microorganisms belonging to *Pseudomonas, Bacillus,Aspergillus* and other groups increase the supply of phosphorus. These microorganisms produce organic acids and other bioactive molecules which in turn increase the availability of soil phosphorus, and consequently P uptake, growth and yield of crops. Soil microorganisms possessing phytase activity can contribute to plant-phosphorus nutrition through phytate mineralization (Idriss *et al*., 2002). In addition, an obligatory symbiotic VAM fungus which can also stimulate P absorption in crops by spreading their extensive hyphal growth beyond the nutrient depletion zone of plant roots (Smith and Smith, 1990).

Plant growth promotion

Plant Growth Promoting Rhizobacteria (PGPR) is a group of microorganisms have potential to increase crop yields through production of phytohormones and other biomolecules involved in the control of soil-borne diseases are PGPR (table 5) and their effects on plant growth are mediated by direct or indirect mechanisms. The direct effects are attributed to the production of plant hormones such as auxins, gibberellins and cytokinin's as well as siderophores. Siderophores may also help the plant with sufficient iron in iron-limited soils. On the other hand, the indirect effect includes control of soil pathogens by bio-control mechanisms through production of antibiotics, hydrogen cyanide (HCN), ammonia and siderophores. HCN production of PGPRs can affect therespiratory system of pathogenic fungi and results in their growth inhibition (Martinez-Viveros *et al*., 2010; Verma *et al*., 2015). Further, lytic enzymes, viz. chitinase and glucanase, produced by these PGPRs can degrade cell wall of fungal pathogens. The PGPRs can also compete with the pathogens for nutrients or for colonization of space and these can further induce systematic resistance throughout the entire plant system.

Table 5: Beneficial effects of PGPRs in different pulse crops

Plant Growth Promoting Rhizobacteria	Crop
Plant nutrition	
Pseudomonas aeruginosa	Chickpea
Bacillus megaterium	Lentil
Pseudomonas lurida–NPRp15 and Pseudomonas putida–PGRs4	French bean
Bacillus subtilis	Greengram
Phytohormone production	
Pseudomonas aeruginosa	Greengram
Bacillus sp., *Micrococcus* sp., *Pseudomonas* sp.,	Redgram, Blackgram,
Flavobacterium sp., *Serratia* sp.	Greengram, Cowpea, Chickpea
Azotobacter sp., *Bacillus* sp., *Pseudomonas* sp.	Chickpea
Abiotic stress tolerance	
Pseudomonas aeruginosa	Blackgram
Pseudomonas brassicacearum, Pseudomonas marginalis	Greenpea
Pseudomonas fluorescens	Groundnut
Pseudomonas sp.	Greenpea
Siderophore production	
Pseudomonas fluorescens	Groundnut

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Bacillus sp., *Pseudomonas*	Chickpea
Pseudomonas putida, Pseudomonas monteilli	Soybean

Abiotic-stress management

The nodulation and productivity of pulses is limited by abiotic stresses like drought, salinity and high temperature. Many of the PGPRs survive through exopolysaccharide (EPS) production (Chenu and Roberson, 1996) and can help in alleviation of abiotic stresses in pulses.

Conclusion

The potential biofertilizers plays an important role in maintaining the productivity and sustainability of soil systems and in turn helps in increasing the production potential of crops. It serves as a farmer friendly, eco-friendly and cost-effective input that can be easily used in the farms in a wide range of crops. Thus, it can be concluded from the above reviews that biofertilizers serves as a multitude of benefits.

Biofertilizers are low-cost inputs with high benefits in agriculture. Incorporation of micronutrients is essential to increase pulse production in deficient soils of India. About 40% of the pulse-growing regions have low to the medium population of native *Rhizobium*. In these circumstances, productivity of pulse may be increased by 10–12% via seed inoculation with low-cost rhizobia biofertilizer. Biofertilizers supplementing P nutrition in agriculture may be vital in saving the much-needed foreign exchange if we succeed in making the "fixed" P available to crops. AMF inoculant is promising to improve the supply of phosphate and micronutrients like zinc for a variety of pulse crops, while phosphate solubilizers are the best option in rainfed areas of poor P availability. Shortage of adequate quantity of quality biofertilizers is one of the chief limitations in the popularization of biofertilizers. Therefore, efforts are needed to ensure availability of critical inputs like quality biofertilizers at the state level. A combined effort between soil chemists, microbiologists, and agronomists is required to facilitate judicious use of inorganic and microbiological inputs to realize better yields while ensuring the agriculture remains sustainable.

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